

What is claimed is:

- 1 1. A composite electrolyte for use in electrochemical fuel cells, comprising:
2 (i) an inorganic cation exchange material;
3 (ii) a silica-based material; and
4 (iii) a proton conducting polymer-based material, wherein the inorganic cation
5 exchange material comprises about 0.1 wt% to about 99 wt% of the composite
6 electrolyte.
- 1 2. The composite electrolyte of claim 1, wherein the silica-based material comprises
2 about 0.1 wt% to about 70 wt%, and the proton conducting polymer-based material
3 comprises about 0.1 wt% to 99.9 wt% of the composite electrolyte.
- 1 3 The composite electrolyte of claim 1 wherein the inorganic cation exchange material
2 is selected from the group consisting of clay, zeolite, hydrous oxide, and inorganic salt.
- 1 4. The composite electrolyte of claim 3, wherein the clay includes an aluminosilicate-
2 based exchange material selected from the group consisting of montmorillonite, kaolinite,
3 vermiculite, smectite, hectorite, mica, bentonite, nontronite, beidellite, volkonskoite,
4 saponite, magadite, kenyaite, zeolite, alumina, rutile.
- 1 5. The composite material of claim 3, wherein the clay is modified to make it more
2 compatible with organic matrices, a clay modification including exfoliation which helps to
3 separate platelets of inorganic substance.
- 1 6. The composite electrolyte of claim 3, wherein the clay includes a modified
2 montmorillonite consisting of montmorillonite treated with a modifier material selected from
3 a group consisting of aminododecanoic acid, trimethyl stearate ammonium, octadecylamine,
4 and methyl dihydroxy hydrogenated tallow ammonium.
- 1 7. The composite electrolyte of claim 1 wherein the inorganic cation exchange material
2 comprises about 0.1 wt% to about 30 wt%, the silica-based material comprises about 0.1 wt%
3 to about 30 wt%, and the proton conducting polymer-based material comprises about 40 wt%
4 to 99.9 wt% of the composite electrolyte.

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- 1 8. The composite electrolyte of claim 1 wherein the proton conducting polymer-based
2 material has a linear, branched, or network morphology.
- 1 9. The composite electrolyte of claim 1 wherein the proton conducting polymer-based
2 material includes material selected from the group consisting of
3 acrylonitrile/butadiene/styrene rubber (ABS), styrene butadiene/acrylate/acetate polymer
4 blends, epoxides, and a thermoplastic material.
- 1 10. The composite electrolyte of claim 9 wherein the thermoplastic material is selected
2 from a group consisting polypropylene, polycarbonate, polystyrene, polyethylene, polyaryl
3 ethers sulfones, poly aryl ether ketone, and polysulfones.
- 1 11. The composite electrolyte of claim 1 wherein the proton conducting polymer-based
2 material has a functional group element selected from a group consisting of sulfonate,
3 phosphate, carbonate, amide, and imide, wherein each such functional group element has
4 proton conducting capabilities.
- 1 12. The composite electrolyte of claim 1, further comprising an additive selected from a
2 group consisting of preservative, thixotropy and viscosity control agent, crosslinking agent,
3 conditioner, plasticizer, water control agent, and proton conducting material.
- 1 13. The composite electrolyte of claim 1 wherein the inorganic cation exchange material,
2 the silica-based material and the proton conducting polymer-based material comprise 90 wt
3 % or more of the solids content of the composite electrolyte.
- 1 14. The composite electrolyte of claim 1 wherein the composite electrolyte when
2 measured in the substantially dried state consists essentially of the inorganic cation exchange
3 material, the silica-based material and the proton conducting polymer-based material.
- 1 15. The composite electrolyte of claim 1 wherein the composite electrolyte has a proton
2 conductivity of about 0.05 S/cm or higher

- 1 16. The composite electrolyte of claim 1 wherein the silica-based material includes
2 materials containing one or more of silica, silicate, and silicate having an organic element.
- 1 17. The composite electrolyte of claim 1 wherein the silica-based material is either
2 colloidal silica containing discrete spheres of silica or tetraethylorthosilicate.
- 1 18. An electrochemical fuel cell, comprising:
2 (i) an anode;
3 (ii) a cathode;
4 (iii) a fuel supply to the anode;
5 (iv) an oxidant supply to the cathode; and
6 (v) a composite electrolyte positioned between the anode and cathode and
7 including
8 (a) an inorganic cation material,
9 (b) a silica-based binder, and
10 (c) a polymer-based binder,
11 wherein the inorganic cation exchange material comprises about 0.1 wt% to about 99
12 wt%, of the composite electrolyte.
- 1 19. The electrochemical fuel cell of claim 18 wherein the silica-based material comprises
2 about 0.1 wt% to about 70 wt%, and the proton conducting polymer-based material
3 comprises about 0.1 wt% to 99.9 wt% of the composite electrolyte.
- 1 20. The electrochemical fuel cell of claim 18 wherein the inorganic cation exchange
2 material comprises about 0.1 wt% to about 30 wt%, the silica-based material comprises about
3 0.1 wt% to about 30 wt%, and the proton conducting polymer-based material comprises
4 about 40 wt% to 99.9 wt% of the composite electrolyte.
- 1 21. The electrochemical fuel cell of claim 18 wherein the inorganic cation exchange
2 material is selected from the group consisting of clay, zeolite, hydrous oxide, and inorganic
3 salt.
- 1 22. The electrochemical fuel cell of claim 21 wherein the clay includes an
2 aluminosilicate-based exchange material selected from the group consisting of

3 montmorillonite, kaolinite, vermiculite, smectite, hectorite, mica, bentonite, nontronite,
4 beidellite, volkonskoite, saponite, magadite, kenyaite, zeolite, alumina, and rutile.

1 23. The electrochemical fuel cell of claim 21, wherein the clay is modified to make it
2 more compatible with organic matrices, a clay modification including exfoliation which helps
3 to separate platelets of inorganic substance.

1 24. The electrochemical fuel cell of claim 21, wherein the clay includes a modified
2 montmorillonite consisting of montmorillonite treated with a modifier material selected from
3 a group consisting of aminododecanoic acid, trimethyl stearate ammonium, octadecylamine,
4 and methyl dihydroxy hydrogenated tallow ammonium.

1 25. The electrochemical fuel cell of claim 18 wherein the polymer-based material has
2 linear, branched, or network morphology.

1 26. The electrochemical fuel cell of claim 18 wherein the polymer-based material
2 includes material selected from the group consisting of acrylonitrile/butadiene/styrene rubber
3 (ABS), styrene butadiene/acrylate/acetate polymer blends, epoxides, polypropylene,
4 polycarbonate, polystyrene, polyethylene, polyaryl ethers, and polysulfones.

1 27. The electrochemical fuel cell of claim 18 wherein the inorganic cation exchange
2 material, the silica-based material and the polymer-based material comprise 90 wt % or more
3 of the solids content of the composite electrolyte.

1 28. The electrochemical fuel cell of claim 18 wherein the composite electrolyte when
2 measured in the substantially dried state consists essentially of the inorganic cation exchange
3 material, the silica-based material and the polymer-based material.

1 29. The electrochemical fuel cell of claim 18 wherein the composite electrolyte has a
2 proton conductivity of about 0.05 S/cm or higher.

1 30. A method of fabricating a composite electrolyte for use in an electrochemical fuel
2 cell, comprising:

3 (i) applying onto a surface of a substrate a viscous liquid composition of (a) an
4 inorganic cation exchange material, (b) silica-based material, (c) a polymer-
5 based material, and (d) a solvent-dispersant;
6 (ii) spreading the viscous liquid composition to form a uniform thickness layer on
7 the substrate; and
8 (iii) allowing the solvent to evaporate from the viscous liquid composition to yield
9 the composite electrolyte,
10 wherein the inorganic cation exchange material comprises about 0.1 wt% to
11 about 99 wt% of the composite electrolyte.

1 31. The method of claim 30, wherein the silica-based material comprises about 0.1 wt%
2 to about 70 wt%, and the polymer-based material comprises about 0.1 wt% to 99.9 wt% of
3 the composite electrolyte.

1 32. The method of claim 30 wherein step (ii) includes drawing the viscous liquid
2 composition through a doctor blade assembly.

1 33. The method of claim 30 wherein step (iii) includes heating the viscous liquid
2 composition.

1 34. The method of claim 30 wherein the inorganic cation exchange material comprises
2 about 0.1 wt% to about 30 wt%, the silica-based material comprises about 0.1 wt% to about
3 15 wt%, and the polymer-based material comprises about 40 wt% to 99 wt% of the composite
4 electrolyte.

1 35. The method of claim 19 wherein the inorganic cation exchange material is selected
2 from the group consisting of clay, zeolite, hydrous oxide, inorganic and salt.

1 36. The method of claim 35 wherein the clay includes an aluminosilicate-based exchange
2 material selected from the group consisting of montmorillonite, kaolinite, vermiculite,
3 smectite, hectorite, mica, bentonite, nontronite, beidellite, volkonskoite, saponite, magadite,
4 kenyaite, zeolite, alumina, and rutile.

- 1 37. The method of claim 35, wherein the clay is modified to make it more compatible
2 with organic matrices, a clay modification including exfoliation which helps to separate
3 platelets of inorganic substance.
- 1 38. The method of claim 35, wherein the clay includes a modified montmorillonite
2 consisting of montmorillonite treated with a modifier material selected from a group
3 consisting of aminododecanoic acid, trimethyl stearate ammonium, octadecylamine, and
4 methyl dihydroxy hydrogenated tallow ammonium.
- 1 39. The method of claim 30 wherein the polymer-based material has a linear, branched, or
2 netted morphology.
- 1 40. The method of claim 30 wherein the polymer-based material includes one of
2 acrylonitrile/butadiene/styrene rubber (ABS), styrene butadiene/acrylate/acetate polymer
3 blends, epoxides, polypropylene, polycarbonate, polystyrene, polyethylene, polyaryl ethers,
4 and polysulfones.
- 1 41. The method of claim 30 wherein the solvent-dispersant comprises water, N-methyl
2 pyrrolidinone, dimethyl sulfoxide, dimethyl acidimide, and dimethylformamide.
- 1 42. The method of claim 30 wherein the inorganic cation exchange material, the silica-
2 based material and the polymer-based material comprise 90 wt % or more of the solids
3 content of the composite electrolyte.
- 1 43. The method of claim 30 wherein the composite electrolyte when measured in the
2 substantially dried state consists essentially of the inorganic cation exchange material, the
3 silica-based material and the polymer-based material.
- 1 44. The method of claim 19 wherein the composite electrolyte has a proton conductivity
2 of about 0.05 S/cm or higher.
- 1 45. A method for producing a composite membrane, comprising:

- 2 (i) grinding a sulfonated polyether ether ketone (SPEEK) and clay mixture and
- 3 dissolving the mixture in a distilled dimethylformamide (DMF) to form a solution;
- 4 (ii) heating the solution until it thickens and attains a casting consistency;
- 5 (iii) degassing the solution in a vacuum oven;
- 6 (iv) casting the solution into a film on a glass surface using a doctor blade;
- 7 (v) curing the film; and
- 8 (vi) peeling the film from the glass.

1 46. The method of claim 45, wherein the dissolving in step (i) is performed by stirring
2 for about 2 hours using a magnetic stir bar.

1 47. The method of claim 45, wherein the solution is stirred while heated, and wherein the
2 DMF evaporates.

1 48. The method of claim 45, wherein the film is about 60 μm thick.

1 49. The method of claim 45, wherein the curing includes,
2 (a) annealing the film in a convection oven, and
3 (b) maintaining the film in a vacuum for a predetermined time period at a
4 predetermined temperature.

1 50. The method of claim 45, further comprising:
2 storing the film in ultra-pure water until it is ready for use.